CLAIMS

What is claimed is:

1. An apparatus for use with a transfer system for transferring a trolley between first and second stations, the system including an inhaul winch, an outhaul winch, a cable and a trolley, the inhaul winch mounted to the first station, the outhaul winch mounted to one of the first and second stations, the cable extending between the first and second stations and between the inhaul and outhaul winches and the trolley mounted to the cable, the assembly for controlling trolley speed during transfer between the first and second stations and comprising:

a speed selector for setting a command speed value;

a speed sensor assembly sensing the speed of the cable and providing a speed feedback value; and

a speed regulator regulating the speeds of the inhaul and the outhaul winches as a function of the command speed value and the speed feedback value.

2. The apparatus of claim 1 wherein the speed sensor assembly includes an inhaul speed sensor, an outhaul speed sensor and a feedback determiner, the inhaul speed sensor sensing the speed of the cable proximate the inhaul winch and generating an inhaul speed feedback signal and the outhaul speed sensor sensing the speed of the cable proximate the outhaul winch and generating an outhaul speed feedback signal, the feedback determiner selecting one or the other of the inhaul and outhaul speed feedback signals as the speed feedback value.

3. The apparatus of claim 2 wherein, when the winches are moving the trolley from the first station toward the second station, the feedback determiner selects the inhaul speed feedback signal as the speed feedback value and, when the winches are moving the trolley from the second station toward the first station, the feedback determiner selects the outhaul speed feedback signal as the speed feedback value.

4. The apparatus of claim 1 further including a pulley mounted to the second station and wherein the outhaul winch is mounted to the first station and the cable passes from the inhaul winch around the pulley and back to the outhaul winch.

5. The apparatus of claim 1 wherein the speed sensor assembly includes first and second cable speed sensors for determining the speed of two different sections of the cable.

6. The apparatus of claim 5 wherein the speed sensor assembly further includes a speed feedback determiner for selecting a signal from one of the first and second cable speed sensors as the speed feedback value.

7. The apparatus of claim 6 wherein the first and second speed sensors include an inhaul speed sensor for sensing the speed of the cable proximate the inhaul winch and an outhaul speed sensor for sensing the speed of the cable proximate the outhaul winch, respectively, and, wherein, the speed feedback determiner selects the inhaul sensor signal when the inhaul winch is letting cable out and selects the outhaul sensor signal when the outhaul winch is letting cable out.

8. The apparatus of claim 1 wherein the speed regulator includes a summer that mathematically combines the command speed value and the speed feedback value to generate a speed error value and then uses the speed error value to adjust inhaul and outhaul winch speeds.

9. The apparatus of claim 8 wherein, when the speed error value is positive, the speed regulator uses the speed error value as an intermediate outhaul speed value to control the outhaul winch and a zero intermediate inhaul speed value to control the inhaul winch and, when the speed error value is negative, the speed regulator uses the speed error value as an intermediate inhaul speed value to control the inhaul winch and a zero intermediate outhaul speed value to control the outhaul winch.

10. The apparatus of claim 9 further including a tension selector for setting a command tension value, the speed regulator mathematically combining the command tension value and the intermediate inhaul speed value to generate an inhaul torque value to control the inhaul winch speed and mathematically combining the command tension value and the intermediate outhaul speed value to generate an outhaul torque value to control the outhaul winch speed.

11. The apparatus of claim 10 further including inhaul and outhaul tension sensors for sensing cable tensions proximate the inhaul and outhaul winches and generating inhaul and outhaul tension feedback values, respectively, when the error signal is negative, the speed regulator mathematically combining to generate the outhaul torque value by:

mathematically combining the command tension value and the outhaul tension feedback value to generate an intermediate outhaul tension value;

mathematically combining the command tension value and the intermediate outhaul tension value to generate a final outhaul tension value; and

mathematically combining the intermediate outhaul speed value and the final outhaul tension value to generate the outhaul torque value; and,

when the error signal is positive, the speed regulator mathematically combining to generate the inhaul torque value by:

mathematically combining the command tension value and the inhaul feedback tension value to generate an intermediate inhaul tension value;

mathematically combining the command tension value and the intermediate inhaul tension value to generate a final inhaul tension value; and

mathematically combining the intermediate inhaul speed value and the final inhaul tension value to generate the inhaul torque value.

12. The apparatus of claim 11 wherein the summer mathematically combines the command speed value and the speed feedback value by subtracting the speed feedback value from the command speed value.

13. The apparatus of claim 1 further including a cable tension selector for selecting a cable tension command value, the speed regulator regulating the speeds of the inhaul and the outhaul winches as a function of the command speed value, the speed feedback value and the cable tension command value.

14. The apparatus of claim 13 further including an inhaul cable tension sensor and an outhaul cable tension sensor for sensing the tension of the cable proximate the inhaul and outhaul winches and generating inhaul and outhaul tension feedback values, respectively, the speed regulator regulating the speeds of the inhaul and the outhaul winches as a function of the command speed value, the

speed feedback value, the cable tension command value and the inhaul and outhaul tension feedback values.

15. The apparatus of claim 14 wherein the speed sensor assembly includes first and second cable speed sensors for determining the speeds of two different sections of the cable and wherein the speed sensor assembly further includes a speed feedback determiner for selecting a signal from one of the first and second cable speed sensors as the speed feedback value.

16. An apparatus for use with a transfer system for transferring a trolley between first and second stations, the system including an inhaul winch, an outhaul winch, a cable, a trolley and a pulley, the inhaul winch and outhaul winch mounted to the first station, the pulley mounted to the second station, the cable extending from the inhaul winch to the pulley and back to the outhaul winch and the trolley mounted to the cable, the assembly for controlling trolley speed during transfer between the first and second stations and comprising:

a speed selector for setting a command speed value, the command speed value positive when the winches are operating to move the trolley toward the second station and negative when the winches are operating to move the trolley toward the first station;

an inhaul speed sensor for sensing cable speed proximate the inhaul winch and generating an inhaul speed feedback value;

an outhaul speed sensor for sensing cable speed proximate the outhaul winch and generating an outhaul speed feedback value;

a speed feedback determiner that selects the inhaul speed feedback value as a speed feedback value when the command speed value is positive and selects the outhaul speed feedback value as the speed feedback value when the command speed value is negative; and

a speed regulator that regulates the torques of the inhaul and the outhaul winches as a function of the command speed value and the speed feedback value.

17. The apparatus of claim 16 wherein the speed regulator includes a summer that mathematically combines the command speed value and the speed feedback value to generate a speed error value and uses the speed error value to adjust the inhaul and outhaul winch torques.

18. The apparatus of claim 17 wherein, when the speed error value is positive, the speed regulator uses the speed error value as an intermediate outhaul speed value to control the outhaul winch and a zero intermediate inhaul speed value to control the inhaul winch and, when the speed error value is negative, the speed regulator uses the speed error value as an intermediate inhaul speed value to control the inhaul winch and a zero intermediate outhaul speed value to control the outhaul winch.

19. The apparatus of claim 18 further including a tension selector for setting a command tension value, the speed regulator mathematically combining the command tension value and the intermediate inhaul speed value to generate an inhaul torque value to control the inhaul winch speed and mathematically combining the command tension value and the intermediate outhaul speed value to generate an outhaul torque value to control the outhaul winch speed.

20. The apparatus of claim 19 further including inhaul and outhaul tension sensors for sensing the cable tensions proximate the inhaul and outhaul winches and generating inhaul and outhaul tension feedback values, respectively, the speed regulator using the inhaul and outhaul tension feedback signals to generate the inhaul and outhaul torque values.

21. The apparatus of claim 20 wherein, when the error signal is negative, the speed regulator mathematically combines to generate the outhaul torque value by:

mathematically combining the command tension value and the outhaul tension feedback value to generate an intermediate outhaul tension value;

mathematically combining the command tension value and the intermediate outhaul tension value to generate a final outhaul tension value; and

mathematically combining the intermediate outhaul speed value and the final outhaul tension value to generate the outhaul torque value; and,

when the error signal is positive, the speed regulator mathematically combining to generate the inhaul torque value by:

mathematically combining the command tension value and the inhaul tension feedback value to generate an intermediate inhaul tension value;

mathematically combining the command tension value and the intermediate inhaul tension value to generate a final inhaul tension value; and

mathematically combining the intermediate inhaul speed value and the final inhaul tension value to generate the inhaul feedback value.

22. The apparatus of claim 21 wherein the summer mathematically combines the command speed value and the speed feedback value by subtracting the speed feedback value from the command speed value.

23. A method for use with a transfer system for transferring a trolley between first and second stations, the system including an inhaul winch, an outhaul winch, a cable, a trolley and a pulley, the inhaul winch and outhaul winch mounted to the first station, the pulley mounted to the second station, the cable extending from the inhaul winch to the pulley and back to the outhaul winch and the trolley mounted to the cable, the method for controlling trolley speed during transfer between the first and second stations and comprising the steps of:

providing a command speed value that is positive when the trolley is being moved from the first toward the second station and that is negative when the trolley is being moved from the second to toward the first station;

identifying an inhaul speed feedback value by determining the speed of a section of the cable proximate the inhaul winch;

identifying an outhaul speed feedback value by determining the speed of a section of the cable proximate the outhaul winch;

when the command speed value is positive, selecting the inhaul speed feedback value as a speed feedback value;

when the command speed value is negative, selecting the outhaul speed feedback value as a speed feedback value; and

regulating winch torques as a function of the command speed value and the speed feedback value.

24. The method of claim 23 wherein the step of regulating as a function of the speed feedback value includes subtracting the speed feedback value form the command speed value to generate a speed error value, when the speed error value is positive, increasing the outhaul winch torque and, when the speed error value is negative, increasing the inhaul winch torque.

25. The method of claim 24 further including the step of providing a command tension value and wherein the step of regulating winch torques includes regulating the torques as a function of both the speed error value and the command tension value.

26. The method of claim 25 wherein the step of regulating torques includes, when the speed error value is positive, multiplying the command tension value and an inhaul scaling factor to generate an inhaul torque value and using the inhaul torque value to regulate the inhaul winch torque and mathematically combining the command tension value and the speed error value to generate an outhaul torque value and using the outhaul torque value to control the outhaul winch torque and, when the speed error value is negative, multiplying the command tension value and an outhaul scaling factor to generate an outhaul torque value and using the outhaul torque value to regulate the outhaul winch torque and mathematically combining the command tension value and the speed error value to generate an inhaul torque value and using the inhaul torque value to control the inhaul winch torque.

27. The method of claim 26 wherein the step of mathematically combining to generate an outhaul torque value includes the step of multiplying the command tension value and an outhaul scaling factor to generate a scaled outhaul tension value and adding the scaled outhaul tension value and the speed error value to generate the outhaul torque value and, wherein, the step of mathematically combining to generate an inhaul torque value includes the step of multiplying the command tension value and an inhaul scaling factor to generate a scaled inhaul value and adding the scaled inhaul value and the speed error value to generate the inhaul torque value.

28. The method of claim 25 further including the steps of identifying an inhaul tension feedback value by determining the tension of a section of the cable proximate the inhaul winch, identifying an outhaul tension feedback value by determining the tension of a section of the cable proximate the outhaul winch and, wherein, the step of regulating torques includes, when the speed error value is positive, mathematically combining the command tension value and the inhaul feedback tension value to generate an inhaul torque value and using the inhaul torque value to regulate the inhaul winch torque and mathematically combining the command tension value and an outhaul scaling factor to generate an outhaul torque value and using the outhaul torque value to regulate the outhaul winch torque and, when the speed error value is negative, mathematically combining the command

tension value and the outhaul feedback tension value to generate an outhaul torque value and using the outhaul torque value to regulate the outhaul winch speed and mathematically combining the command tension value and an inhaul scaling factor to generate an inhaul torque value and using the inhaul torque value to regulate the inhaul winch speed.

29. The method of claim 28 wherein the step of mathematically combining the command tension value and the inhaul feedback tension value to generate an inhaul torque value includes mathematically combining the command tension value, the inhaul feedback tension value and an inhaul scaling factor to generate the inhaul torque value and, wherein, the step of mathematically combining the command tension value and the outhaul feedback tension value to generate an outhaul torque value includes mathematically combining the command tension value, the outhaul feedback tension value and an outhaul scaling factor to generate the outhaul torque value.

30. A transfer assembly for transferring between first and second stations, the assembly comprising:

an inhaul winch mounted to the first station;

an outhaul winch mounted to one of the first and second stations;

a cable extending between the first and second stations and between the inhaul and outhaul winches;

a trolley mounted to the cable;

a speed selector for setting a command speed value;

a speed sensor assembly sensing the speed of the cable and providing a speed feedback value; and

a speed regulator regulating the speeds of the inhaul and the outhaul winches as a function of the command speed value and the speed feedback value.

31. The assembly of claim 30 wherein the speed sensor assembly includes first and second cable speed sensors for determining the speed of two different sections of the cable.

32. The assembly of claim 31 wherein the speed sensor assembly further includes a speed feedback determiner for selecting a signal from one of the first and second cable speed sensors as the speed feedback value.

33. The assembly of claim 32 wherein the first and second speed sensors include an inhaul speed sensor for sensing the speed of the cable proximate the inhaul winch and an outhaul speed sensor for sensing the speed of the cable proximate the outhaul winch, respectively, and, wherein, the speed feedback determiner selects the inhaul sensor signal when the inhaul winch is letting cable out and selects the outhaul sensor signal when the outhaul winch is letting cable out.

34. The assembly of claim 30 wherein the speed regulator includes a summer that mathematically combines the command speed value and the speed feedback value to generate a speed error value and then uses the speed error value to adjust inhaul and outhaul winch speeds.

35. The assembly of claim 34 wherein, when the speed error value is positive, the speed regulator uses the speed error value as an intermediate outhaul speed value to control the outhaul winch and a zero intermediate inhaul speed value to control the inhaul winch and, when the speed error value is negative, the speed regulator uses the speed error value as an intermediate inhaul speed value to control the inhaul winch and a zero intermediate outhaul speed value to control the outhaul winch.

36. The assembly of claim 35 further including a tension selector for setting a command tension value, the speed regulator mathematically combining the command tension value and the intermediate inhaul speed value to generate an inhaul torque value to control the inhaul winch speed and mathematically combining the command tension value and the intermediate outhaul speed value to generate an outhaul torque value to control the outhaul winch speed.

37. The assembly of claim 36 further including inhaul and outhaul tension sensors for sensing cable tensions proximate the inhaul and outhaul winches and generating inhaul and outhaul tension feedback values, respectively, when the error signal is negative, the speed regulator mathematically combining to generate the outhaul torque value by:

mathematically combining the command tension value and the outhaul tension feedback value to generate an intermediate outhaul tension value;

mathematically combining the command tension value and the intermediate outhaul tension value to generate a final outhaul tension value; and

mathematically combining the intermediate outhaul speed value and the final outhaul tension value to generate the outhaul torque value; and,

when the error signal is positive, the speed regulator mathematically combining to generate the inhaul torque value by:

mathematically combining the command tension value and the inhaul feedback tension value to generate an intermediate inhaul tension value;

mathematically combining the command tension value and the intermediate inhaul tension value to generate a final inhaul tension value; and

mathematically combining the intermediate inhaul speed value and the final inhaul tension value to generate the inhaul torque value.

38. The assembly of claim 37 wherein the summer mathematically combines the command speed value and the speed feedback value by subtracting the speed feedback value from the command speed value.

39. The assembly of claim 30 further including a cable tension selector for selecting a cable tension command value, the speed regulator regulating the speeds of the inhaul and the outhaul winches as a function of the command speed value, the speed feedback value and the cable tension command value.

40. The assembly of claim 39 further including an inhaul cable tension sensor and an outhaul cable tension sensor for sensing the tension of the cable proximate the inhaul and outhaul winches and generating inhaul and outhaul tension feedback values, respectively, the speed regulator regulating the speeds of the inhaul and the outhaul winches as a function of the command speed value, the speed feedback value, the cable tension command value and the inhaul and outhaul tension feedback values.

41. The assembly of claim 40 wherein the speed sensor assembly includes first and second cable speed sensors for determining the speeds of two different sections of the cable and wherein the speed sensor assembly further includes a speed feedback determiner for selecting a signal from one of the first and second cable speed sensors as the speed feedback value.